# LDCM Pixel-to-Pixel Uniformity Specification Rationale

This document is intended to provide insight into the rationale behind the four components of the LDCM Pixel-to-Pixel Uniformity (PPU) Specification (*specification is stated in italics*). In all cases, a created example is shown of the effect the specification seeks to address.

Recently MIT/LL derived the on-orbit PPU uniformity corrections for flat-field ALI using Ross Ice Shelf images acquired Spring 2001. After deriving and reapplying these corrections, the ALI 3 sigma peak-to-peak PPNU was determined to be ~0.25%.

### *6.2.3 Pixel-to-Pixel Uniformity*

#### *6.2.3.1 Full Field of View*

*For a spatially uniform source above 2*$L_{typical}$, the standard deviation of the calibrated values across all pixels within a line of LDCM Level 1R Digital Image Data within a band shall not exceed 0.25% of the average radiance. Temporal (within column) noise may be averaged to verify compliance with this specification.*

This specification seeks to address overall gross non-uniformities that are slowly varying. As an example, figure 1 shows the non-uniformity that may result if a non-Lambertian calibration target is use to flat field and/or calibrate an imager. If a calibration source has an angular fall-off of radiance then the image data will be over corrected as one moves off nadir. When one considers a push-broom instrument that depends on a stable BRDF of its solar diffuser panel to flat field, such as MISR, one could conceive of this type of PPNU happening as the diffuser degrades on-orbit.

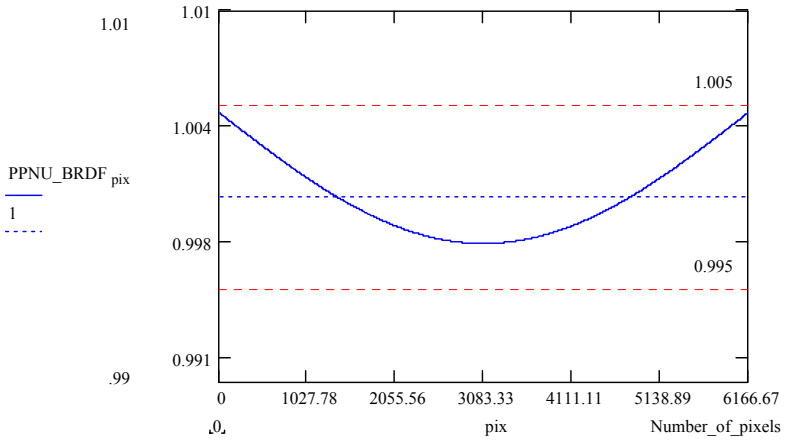


**Figure 1: Hypothetical Cosine Curvature that might result from Calibration Source Angular or Spatial Non-Uniformity. (This meets the 6.2.3.1 requirement.)**

The ALI instrument also meets this specification since 99.7% (+/- 3 sigma) of its pixels have a non-uniformity (NU) <0.25%.

#### *6.2.3.2 Banding*

a. *For a spatially uniform source above 2*$L_{typical}$, the root mean square of the deviation from the average radiance across the line for any 100 contiguous pixels within a line of LDCM Level 1R Digital Image Data within a band shall not exceed 0.5%. Temporal (within column) noise may be averaged to verify compliance with this specification.*

This specification will address the banding that has smoothly varying "edges" such as a rapid roll-off on the edges due to poor flat-fielding, or peaks due to pathological cases where adjacent Sensor Chip Assembly (SCA) non-uniformities have equal and opposite slopes which produce some sort of triangular or trapezoidal non-uniformity; or a number of small steps that lead to larger deviation from the average.

This specification limits the maximum non-uniformity of a block of pixels greater than 100 wide to 0.5%. Figures 2 & 3 are an example of where this specification would apply. Figure 2 demonstrates a case that easily meets all of the PPNU specifications. Figure 3 does not meet this section's specification since 100 pixels taken from the central SCA of the peak are >0.5% from the overall average radiance.

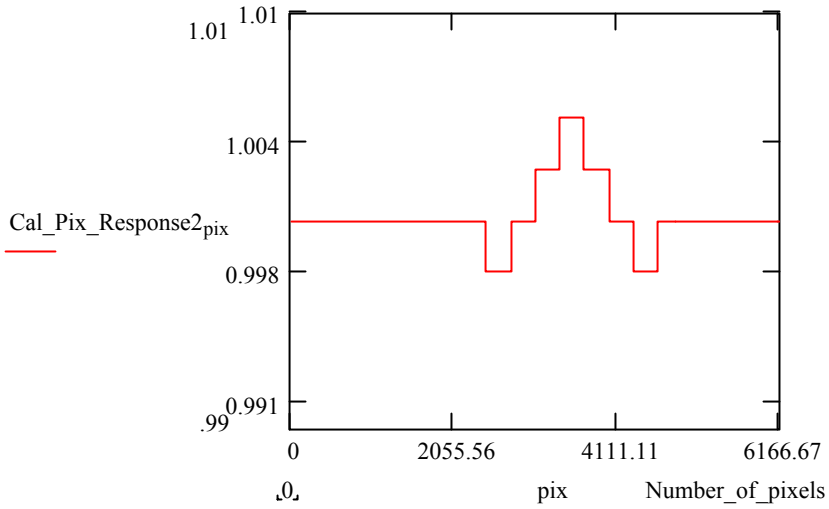


**Figure 2: SCA Level Shifts in a Hypothetical LDCM Line that do not Exceed 6.2.3.2.a's Spec (Assuming a fully populated ALI focal Plane Assembly of 20 SCA's)**

In both cases, the data also meet the Full Field of View specification of 6.2.3.1 since the STDEV of the overall is only 0.158%. This is due to fact that the banding offsets are averaged over 20 SCA's. The SCA to SCA step sizes are <0.5% so both part "b." (STDDEV of 100 pix) and 6.2.3.3 (Streaking) are met.

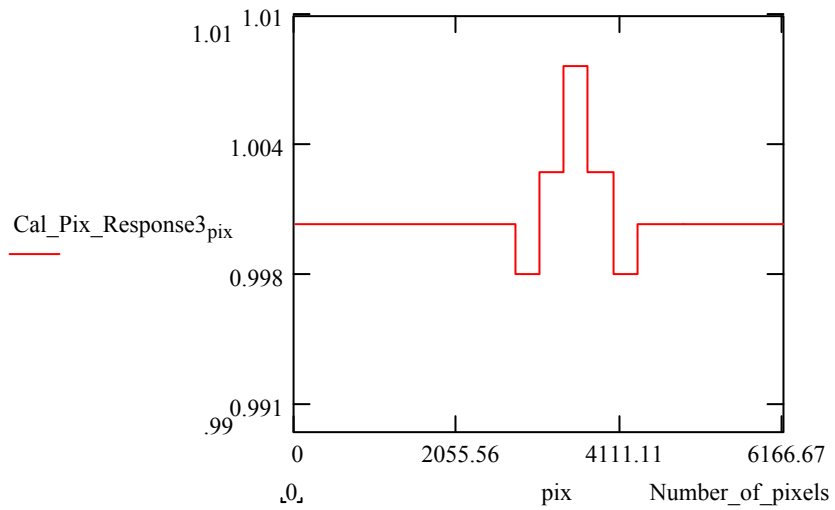


**Figure 3: SCA Level Shifts in a Hypothetical LDCM Line that Exceed 6.2.3.2.a's Spec (Assuming a fully populated ALI focal Plane Assembly of 20 SCA's)**

The ALI instrument also meets this specification since 99.7% (+/- 3 sigma) of its pixels have a non-uniformity (NU) <0.25%.

b. *For a uniform source above 2*$L_{typical}$, the standard deviation of the calibrated values across any 100 contiguous pixels within a line of LDCM Level 1R Digital Image Data within a band shall not exceed 0.25% of the average radiance across the line. Temporal (within column) noise may be averaged to verify compliance with this specification.*

This part addresses discontinuities and small bands or stripes that are less than 50 pixels wide. We might have called this a "Striping and Discontinuity" specification. Figure 4 shows a hypothetical example of a banding that is addressed by this specification. The maximum allowable "step" is limited to 0.5%.

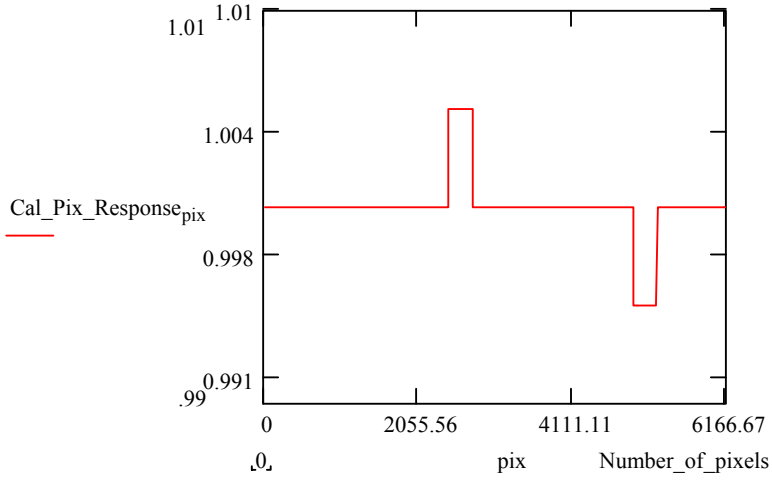


**Figure 4: SCA Level Shifts in a Hypothetical LDCM Line that meet 6.2.3.2.b's Spec (Assuming a fully populated ALI focal Plane Assembly of 20 SCA's)**

The ALI instrument also meets this specification since 99.7% (+/- 3 sigma) of its pixels have a non-uniformity (NU) <0.25%.

### *6.2.3.3 Streaking*

*For a spatially uniform source above 2*Ltypical, the maximum value of the streaking parameter within a line of Level 1R digital image data shall not exceed 0.50% of the band average radiance for bands 1-7 and 9 or 1.0% of the average radiance for the sharpening band (band 8 or band 4, if the red band is used as the sharpening band). Temporal (within column) noise may be averaged to verify compliance with this specification.*

*The streaking parameter is defined by the following equation:*

$$S_i = 100 \times \left| L_i - \frac{1}{2}\left(L_{i-1} + L_{i+1}\right) \right| / L_i$$

*where:*

*$L_i$ is the calibrated radiance value measured for a pixel at an input radiance level;*

*$L_{i-1}$ and $L_{i+1}$ are similarly defined for the $(i-1)^{th}$ and $(i+1)^{th}$ pixels.*

The Streaking Specification seeks to control column and "comb" like artifacts in the calibrated data. An isolated column streak in a pushbroom imager may result from a pixel that is very non-linear, or has an unstable offset and/or gain. Figure 5 shows a hypothetical example of such an effect.

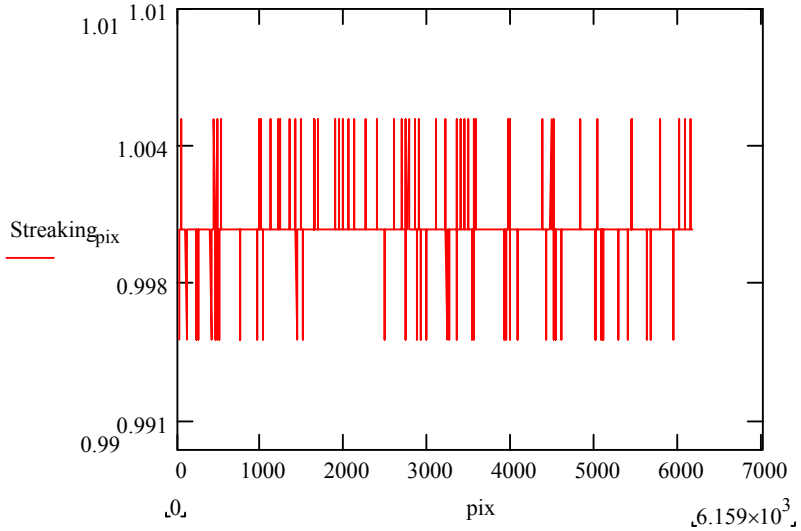


**Figure 5: Hypothetical Streaking Example.**

As a Final Example, figure 6 is a combination of: an over-all slowly varying Overall non-uniformity; Banding (two "bands", one darker and one lighter); and Streaking. This example meets all of the requirements of the LDCM PPNU Specifications.

The ALI instrument likely meets this specification subject to further data reduction and analysis.

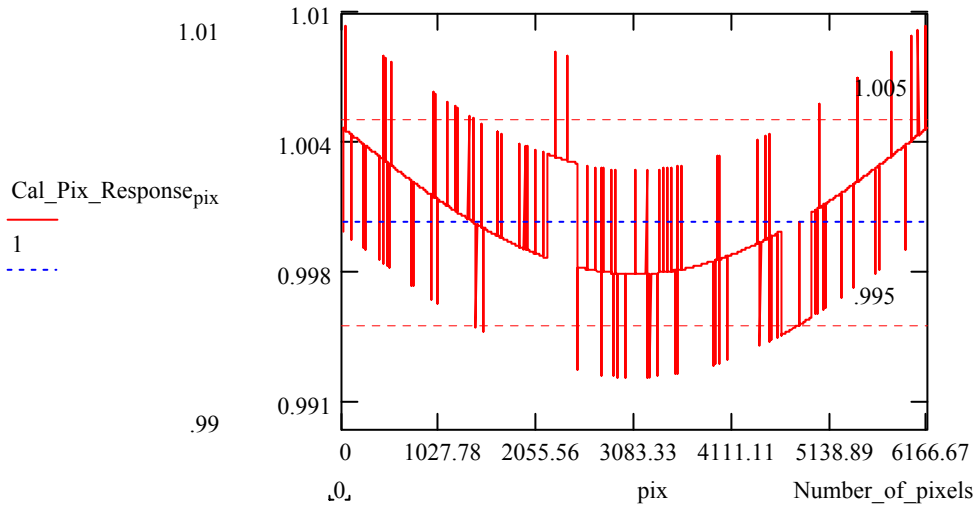


**Figure 6: Combination of: a slowly varying Overall non-uniformity; Banding (two "bands", one darker and one lighter); and Streaking.**

*Note: These requirements apply for target radiances with spectral characteristics as follows: the spectral radiance from bare soil as observed through a dry atmosphere (excluding band 9), spectral radiance proportional to the exoatmospheric solar irradiance, and spectral radiance from a dense vegetation target as observed through a moist atmosphere (excluding band 9) (See Figure 6.2.3-1 and Top of Atmosphere Radiance Values, MODTRAN 4 Model table values, Section 1.5, Reference b). The target radiances are all determined using the same calibration coefficients.*